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MAPPING AND ESTIMATING AREAL EXTENT OF SEVERELY ERODED SOILS OF SELECTED SITES IN NORTHERN INDIANA

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I. INTRODUCTION

The importance of soil conservation and the devastating effects of soil erosion have been noted throughout recorded human history[1]. In the United States it has been estimated that up to two-thirds of the nation's cropland is losing soil at rates up to 5 tons/A (11 mt/ha) while nearly 15% is losing more than 10 ton/A (22 mt/ha) per year[2]. The Soil Conservation Service of the USDA and the Environmental Protection Agency are actively engaged in programs to reduce soil loss and subsequent stream pollution. Rapid methods of pinpointing areas undergoing accelerated erosion are needed to assist in these efforts.

The use of remote sensing techniques such as conventional black and white photography has been utilized in soil survey for many years[3]. In recent years Landsat (formerly ERTS) satellite data have been used in soil mapping for both large scale[4] and more detailed mapping[5,6,7]. Digital analysis techniques developed at LARS have been used to produce spectral maps with a scale as large as 1:15840 which are used to assist in mapping soils in the field.

The objective of this study was to produce a ground cover classification map using computer-implemented analysis of Landsat multispectral scanner data and to evaluate the usefulness of this map in delineating severely eroded soil areas under cultivated conditions.

II. STUDY AREA

A study area of approximately 13 square miles in Whitley County, Indiana was selected. This area is located in the west central part of Whitley County and is characterized by landscapes having moderate to strong slopes (3-15%) on Wisconsin age glacial moraine. The eroded soils in the upland positions in this region are predominantly yellowish brown in color (10YR5/4 to 10YR5/6) and have silty clay loam or clay loam surface textures.

III. DATA SET FORMULATION

Landsat-1 MSS data collected on 9 June 1973 were utilized as the main data source for this study. This scene was selected because the data were 1) of high quality, 2) acquired when most row crop cropland is in a bare soil state, and 3) free of interfering atmospheric and surface conditions (i.e., clouds, haze, saturated soils, and standing water).

The Landsat MSS data were geometrically corrected (i.e., rotated, deskewed, and rescaled to an approximate scale of 1:24,000). That portion of the scene containing Whitley County was selected for further preprocessing. These data were registered to ground control points selected from USGS 7½ minute topographic quadrangles. This procedure produced a data set of an exact scale of 1:24,000 and registered geographic points in the data to their exact ground positions.

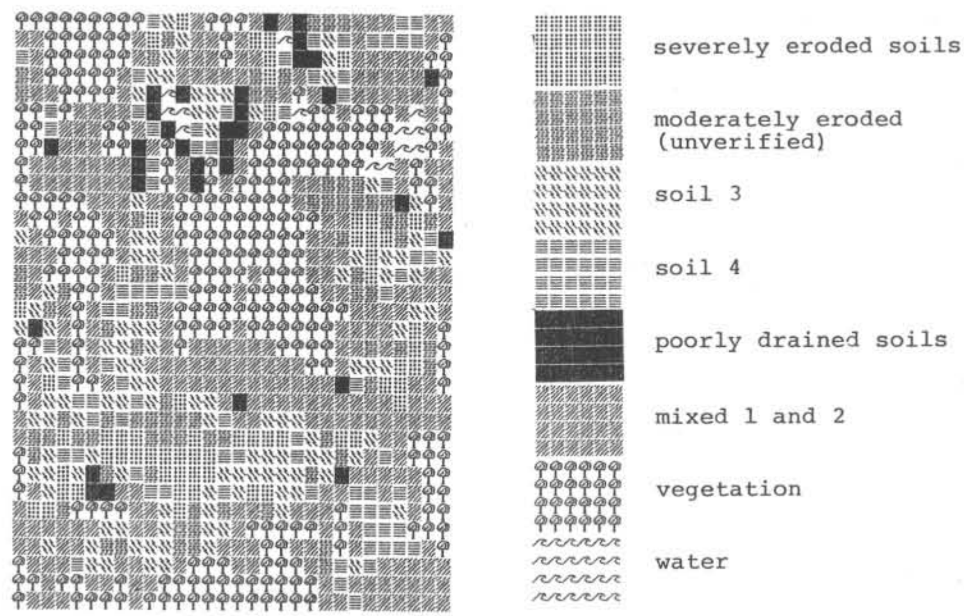
IV. PROCEDURES

This particular study area was selected for input into a cluster algorithm because it was representative for a severely eroded mapping unit in Whitley County. This algorithm divided the MSS data into groups of sample points of similar spectral characteristics. A statistics processor was utilized to calculate the mean relative reflectance values and covariance matrices for each of these individual cluster groupings. Cluster groupings were either deleted, retained, or combined based upon their statistical separability characteristics. This procedure indicated that there were 9 spectrally separable classes within the study area. The statistics developed on each of these 9 classes were used by computer-implemented pattern recognition techniques and by a maximum likelihood Gaussian classifier to assign each of the data points to one of the 9 spectrally separable classes. This technique produced a classification results tape for the study area. From this tape a spectral classification map at a scale of 1:24,000 was produced. This map contained several cover classes which were correlated and verified in the field.

A number of samples of the surface horizon were collected and prepared for laboratory radiometric analysis with an Exotech Model 20C spectroradiometer. The sample preparation and procedures for radiometric scanning are described in another paper presented in this symposium[8].

V. RESULTS AND DISCUSSION

The results of the cluster analysis indicate that in this study area nine classes were clearly separable, two of which were grouped together for display purposes. A classification map of a portion of the study area in Whitley County is shown in Figure 1. The analysis distinguished one vegetation, one water, two mixed and five bare soil classes. The vegetation class in this area is predominantly mixed deciduous forest. The mixed classes probably consist of row crops which have not yet formed a canopy sufficient to completely cover the soil. The five bare soil classes form a continuum from high to low reflectance. Field verification indicates that the class with low reflectance represents the poorly drained soils in the landscape and that the classes with the highest reflectance consistently correlate with the severely eroded upland soils. The second lightest class consistently occupied a position in the landscape adjacent to the severely eroded class. There is some



Total area displayed = 461 ha

Figure 1. Classification Map with Nine Cover Classes for a Portion of the Study Area in Whitley County.

indication that the second lightest class may correlate to moderately or partially eroded soils, but this needs to be substantiated. The area and percentage of each of the ground cover classes in the study area are presented in Table 1.

Table 1. Area and Percentage of Classes in the Whitley County Study Area.

Class Name	Hectares	Percent
severely eroded	121	3.5
moderately eroded (unverified)	208	6.2
soil 3	247	7.4
soil 4	237	7.1
poorly drained	176	5.3
vegetation	1275	38.1
mixed 1 and 2	967	28.8
water	119	3.6
TOTAL	3350	100.0

The bulk of the area is occupied by the woodland and row crop cover classes (38.1 and 28.8%, respectively). The severely eroded cultivated soil and the water classes occupied the smallest area, being 3.5 and 3.6%, respectively. The remaining four soil cover classes covered a range from 5.3 to 7.4% of the study area.

In order to better understand the spectral nature of the soils being studied, several soils were selected and prepared for scanning with the spectral radiometer. A spectral scan of four soils in a Martinsville topographic sequence from White County, Indiana is shown in Figure 2. The lowest soil in the sequence (DEPOSIT) has a dark surface color and represents an accumulation of soils eroded from higher positions in the landscape. The next soil up the sequence (MODERATE) is at the toe slope and has a moderate degree of erosion. The third soil in the sequence (SEVERE) occupies the steepest portion of the slope and is severely eroded. The uppermost soil in the sequence (SURFACE) has little slope and is lightly or non-eroded.

With the exception of the water absorption bands at 1.45 and 1.92 micrometers, it is apparent that as the degree of soil erosion increases (as indicated by changes in the positions in the toposequence), the soil reflectance consistently increases. This consistency is reflected in the consistency with which the lightest bare soil class was correlated to severely eroded areas in the field.

Surface samples were taken from two severely eroded Morley soils in the Whitley County study area. The spectral scan for these two samples is shown in Figure 3. These two soils appear similar in reflectance to the severely eroded soil in the Martinsville sequence. This suggests that even though soils may have differences in parent material or be widely separated geographically, certain properties characteristic to soil erosion may give similar spectral responses. Although the nature of these properties was not investigated in detail in this study, previous and on-going work at LARS indicate that organic matter, clay mineralogy, soil texture, iron and soil moisture content are important factors to be considered in soil reflectance[8,9]. It is likely that one or a combination of these factors is responsible for the distinct spectral patterns of eroded soils.

VI. CONCLUSIONS

Digital analysis of Landsat multispectral data can be used to detect and delineate severely eroded bare soil areas. The characteristics associated with eroded soils cause a higher spectral reflectance which can consistently be detected. Spectral maps of Landsat digital data can be used as a tool for detecting areas undergoing erosion and to assist mapping eroded areas in the field.

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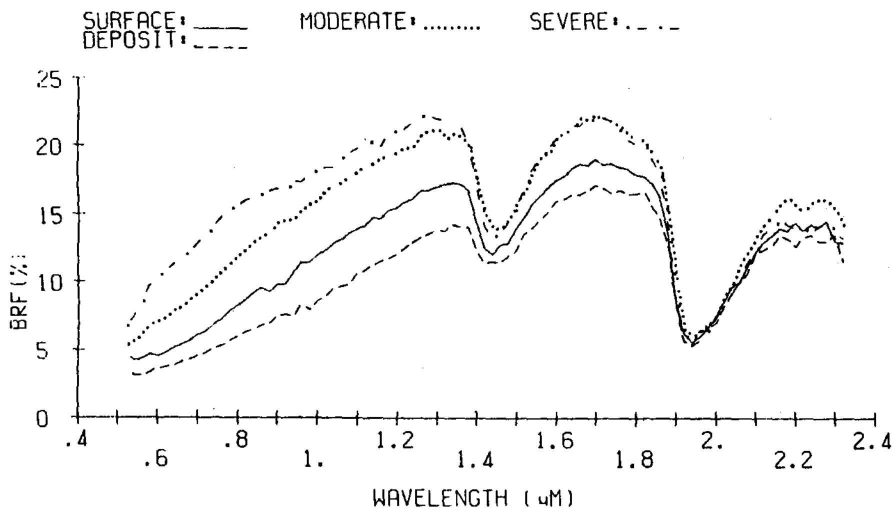

Figure 2. Continuous Spectral Radiometer Scan of the Martinsville Erosion Sequence.

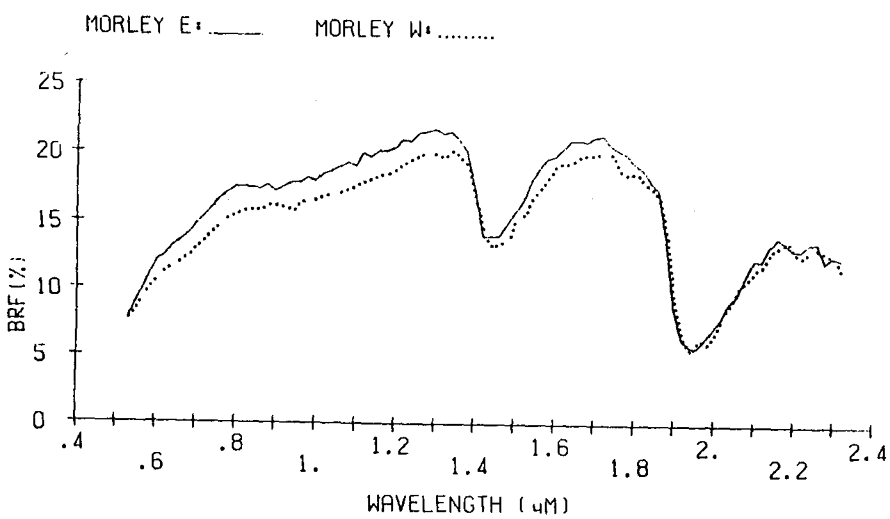

Figure 3. Continuous Spectral Radiometer Scan of Two Morley Soils.

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